POWER TRANSFER SYSTEM WITH REDUCED COMPONENT RATINGS

RELATED APPLICATIONS

[0001] The present application is based on and claims benefit of U.S. Provisional Application Serial No. 60/399,747, filed July 29, 2002, entitled POWER INVERTER WITH REDUCED ENERGY CAPACITY, to which a claim of priority is hereby made.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates generally to energy transfer devices, and relates more particularly to power inverter circuits with reduced component rating.

2. Description of Related Art

[0003] Typical power systems for transferring energy between an input and an output often employ a power inverter that has a DC input and a switched output that can be single or multiple phase. For example, referring to Figure 1, an inverter for driving a three phase motor M is illustrated generally as inverter 10. Inverter 10 operates by switching the power supplied by the plus and minus DC bus lines into motor lines U, V and W to operate motor M. Switches 12a-12f are switched on and off to appropriately direct power to and from motor M in dependency upon the desired power output, control scheme, available DC bus power and other parameters that factor into obtaining a high performance motor drive. Each pair of switches connected between a +DCBUS line and a -DCBUS line form a switching half bridge for delivering power to motor lines U, V and W. For example, switches 12a and 12b form a switching half bridge to drive power signals on motor line U.

[0004] Operation of the half bridge formed by switches 12a-12b is accomplished through standard switching practices to avoid problems associated with component limitations such as switching losses, and to improve system performance. Accordingly, switches 12a and 12b are never switched on at the same time to avoid current shoot through in the motor drive. In addition, a dead time is provided between switching intervals when both switches in the half bridge change state. For example, if switch 12a is to be turned off and switch 12b is to be turned on, these events do not occur simultaneously, but with a delay between switch 12a turning off and switch 12b turning on. When a high frequency inverter drive is used for high performance motor control, the dead time delay becomes important to improve switching frequency without incurring the above discussed drawbacks.

[0005] High frequency switching also produces rapid changes in power transferred from the inverter to the motor and vice versa. These rapid changes in transferred power implies the need of higher power ratings for the switches in the inverter, for example, to handle the potentially large range of power fluctuations.

[0006] Similarly, other components coupled to the inverter, such as passive energy storage components, are rated to withstand potentially large power fluctuations including high peak currents and voltages and large ripple currents and voltages. Referring to Figures 2A and 2B, a passive electrical energy storage component is coupled to inverter 10 to both store input energy, and supply stored energy through inverter 10. Figure 2A shows storage capacitor C_{BUS} coupled between the DC bus lines input to power inverter 10, while Figure 2B shows inductor L_i in the positive DC bus line connected to power inverter 10. In Figure 2A, capacitor C_{BUS} stores electrical energy for power inverter 10 acting as a voltage source inverter, while inductor L_i in Figure 2B acts as a DC link inductor for power inverter 10 acting as a current source inverter. Due to the difficulties associated with energy transfer in power inverter 10 discussed above, the power ratings for the storage components C_{BUS} and L_i must be selected to be high enough to handle the fluctuations in power

without saturating or damaging the passive energy storage components.

[0007] When selecting appropriately rated passive components for use with power inverter 10, the components with appropriate ratings are typically large and somewhat expensive. For example, a typical bus capacitor C_{BUS} comprises a large percentage of a motor drive size and cost. It would be desirable to reduce the rating, and thus the size and cost, of the passive components used with a typical motor drive system.

SUMMARY OF THE INVENTION

[0008] In accordance with the present invention, the inventors have found that the main purpose for including the passive components in the energy transfer circuits for power inverters is to absorb or deliver the difference between the instantaneous input power of the inverter and output power that is applied to a load. The output power applied to the load can be delivered to a motor or a power supply load. When the instantaneous input power tracks with the instantaneous output power, the difference between the instantaneous input power and instantaneous output power can be minimized. Accordingly, the energy to be stored or delivered by the passive component, such as a bus capacitor or DC link inductor can be minimized. For example, the DC bus ripple voltage can be minimized, as well as the DC link ripple current. By determining a particular voltage or current ripple level that can be tolerated by the specific application, the size of the DC bus capacitor or DC link inductor can be minimized accordingly.

[0009] The present invention provides a front end active control for supplying power to the DC bus connected to the power inverter. The front end active control includes a power converter with power factor correction (PFC) to make the power transfer system appear as a purely resistive load to the input power lines. The PFC power converter controls the instantaneous input power to minimize the difference between the instantaneous input power and the instantaneous output power, thereby reducing

the requirements for passive components coupled to the DC bus. The instantaneous output power can be measured or calculated by obtaining values for parameters such as output current or voltage. Typically, one or more of these parameters are measured in most power transfer systems, in particular in motor drive systems, where high performance depends upon closed loop feedback with sensed parameters.

[0010] By reducing the variations in ripple current or voltage and instantaneous input and output power, the rated passive components can be specified at a much lower value, thereby providing reduced packaging size and realizing direct cost reduction.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention is described in detail below with reference to the accompanying drawings, in which:

[0012] Fig. 1 is a circuit diagram of a power inverter coupled to a motor;

[0013] Fig. 2A-2B is a circuit block diagram of a motor drive showing a voltage source inverter and current source inverter, respectively; and

[0014] Fig. 3 is a circuit block diagram according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Referring now to Fig. 3, a control 30 for a motor drive system 31 is shown. Control 30 includes an inverter control 32, and estimator 33 and a power control 34. Inverter control 32 is a closed loop control for inverter 10, using as feedback signals the bus voltage V_{DC} and the bus current I_{DC}. Inverter control 32 provides signals for switching the power switches in inverter 10 according to an appropriate profile to obtain a desired control output for motor M. For example, motor M can be operated for torque control or velocity control based on the switching signals obtained from inverter control 32 in conjunction with the bus feedback signals V_{DC} and I_{DC}. Inverter control 32 can also contribute to realizing soft switching, or switching with zero current, to avoid switching losses. It should be apparent, that inverter control 32

can provide switching signals to operate inverter 10 as a single or multiple phase power supply. Power inverter 10 in motor drive system 31 is a voltage source inverter, due to the presence of bus capacitor C_{BUS}. Capacitor C_{BUS} stores energy from power factor correction (PFC) power supply 35 and supplies energy to inverter 10 to drive output signals conditioned by operation of the power switches in inverter 10. Accordingly, capacitor C_{BUS} is charging and discharging during operation of motor drive system 31, depending upon the conditions of the bus voltage and the amount of energy stored in capacitor C_{BUS}.

[0016] PFC power converter 35 switches power on the DC bus to provide an efficient power conversion of the full wave rectified input signal for use by power inverter 10, while drawing a sinusoidal current that in phase with the input AC voltage to obtain a high power factor. Accordingly, motor drive system 31 appears as a resistive load to the AC input lines coupled to a full wave rectifier 36. Instantaneous input power can easily be measured on the output of full wave rectifier 36 with a simple calculation involving input voltage V_{in} and input current I_{in}. As illustrated in Fig. 3, signals representing input current I_{in} and input voltage V_{in} are multiplied together to produce a signal representative of P_{in}, which in turn is applied to power control 34. Power control 34 also receives an estimate of instantaneous output power from estimator 33, based upon measured bus current I_{DC}.

[0017] Power control 34 receives the signals representative of input power P_{in} and inverter output power P_O and provides bus regulation and control command to PFC power converter 35 to drive the DC bus voltage so that instantaneous input power P_{in} tracks with instantaneous output power P_O. By tracking input power P_{in} with output power P_O, PFC power converter 35 controls the energy on the DC bus that bus capacitor C_{BUS} must handle. With this criteria, the energy, E_c, in bus capacitor C_{BUS}, is minimized.

[0018] Input voltage V_{in} and input current I_{in} are normally measured to obtain a closed loop control for PFC power converter 35 to obtain a good power factor.

Accordingly, input signals representative of input current I_{in} and input voltage V_{in} are typically available in motor drive system 31. In addition, it is often the case that motor speed and/or torque are directly measured with a sensing device. In this instance, estimator 33 is not necessary to obtain a signal representative of output power P_O. That is, directly measured motor speed and torque provide appropriate signals to formulate a signal representative of output power P_O. Because motor speed and torque are typical measurements made in motor drive system 31, control 30 can be further simplified.

[0019] The present invention provides a simple technique to reduce the rating requirements of passive components used in conjunction with inverter power transfer systems. Whether the passive component is a bus capacitor for a voltage source inverter, or a DC link inductor for a current source inverter, the present invention reduces the maximum ratings required for the components. The reduction in component rating requirements greatly reduces the size of the motor drive system, and also greatly reduces overall costs, as the required passive components represent a large percentage of the system cost and size. The PFC power converter operation changes only slightly to ensure input power tracks with output power while also drawing a sinusoidal input current in phase with the input voltage. The DC bus ripple voltage or DC link ripple current is minimized to produce a lower ripple requirement for the passive component. In addition, the energy handled by the passive component is minimized based on the application, again providing for a reduced rating for the passive component.

[0020] Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.